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A CHEMICAL FIRE RETARDANT

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By Harry R. Miller and Carl C. Wilson, foresters,

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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Water has always been a useful fire-fighting tool, but fire fighters have felt that some chemical might be added to increase its striking power and make its effect last longer. Preliminary tests[1/] conducted in 1955 showed that sodium calcium borate was one chemical that could do this job. For control of brush and grass fires, it proved better than water alone because it remained effective for a long time and permitted treating the fuel well in advance of the fire. Field trials in 1956 have substantiated the early findings.

Fire fighters used the borate in as many situations as possible to give it a crucial trial. We wanted to find out not only what the chemical could do, but also what it couldn't do. Therefore, seven conventional ground tankers--slightly modified to use borate--were spotted throughout the state for tests in a wide variety of fuels and burning conditions.[2/] When a fleet of air tankers (crop-duster airplanes converted for bulk water drops) were placed under contract in August, they also used the borate to determine its advantages and limitations in aerial application.

We expected some difficulties in mixing and applying the chemical with conventional equipment. The difficulties developed. At first, mixing the water-borate slurry was a headache, particularly for the air tankers, but by the end of the fire season a solution was at hand. Laboratory tests (see appendix) had suggested that friction loss in hose lines at low flow and abrasiveness would be the major problems in using pumps designed for water. In the field trials with ground tankers the greatest problem was to keep the pump packing tight enough to hold adequate pressure and still not burn the pump shaft. The California Division of Forestry, which had 5 test tanker units in 1956, is not going to use the borate in conventional fire trucks except in emergency situations until satisfactory pumping equipment is developed. But the results of field use were so overwhelmingly favorable that we believe an equipment development program is justified to overcome the mechanical difficulties.

1/ Miller, Harry R. Chemical fire retardants for wild land fire control. Calif. Forest and Range Expt. Sta. Forest Research Note 105, 4 pp. 1956.

2/ Cooperators in the ground-tanker trials were: California State Division of Forestry; Los Angeles County Fire Department; Region 5, U.S. Forest Service; United States Borax & Chemical Corporation.

MIXING THE CHEMICAL WITH WATER

A device that introduces the borate powder into a stream of water promises to solve most mixing problems. Though developed for air operations and given only limited field trials during the 1956 fire season, it seems adaptable to use with both ground and air tankers. Meanwhile field crews tried several improvised methods, and an account of their use may save other workers some grief.

Ground Tankers

Each of the seven standard pumper tankers was modified slightly for the field tests. An opening was made in the top plate of the tank so that dry chemical could be poured easily into the water. Agitation for mixing was obtained by leading a bypass pipe from the pump back to the bottom of the tank. A hard line from the live reel was also placed in the top of the tank to assist the mixing process (fig. 1).

Packing difficulties were serious with a mixture of 5 pounds of chemical per gallon of water, so the rate of mix was cut to 4 pounds per gallon. Fuel coverage was adequate at this rate. Mixtures of less than 3 pounds per gallon did not adhere properly to certain fuels, and did not results in effective coverage. The

Figure 1. --Chemical retardant being mixed in a fire truck.

slurry resulting from mixing 4 pounds of sodium calcium borate to 1 gallon of water weighs about 10.1 pounds per gallon. (Weights and volumes at various concentrations are given in fig. 11, appendix.)

Because mixing the chemical in the truck is both slow and messy, one California Division of Forestry unit devised a 50-gallon drum with hand-powered paddles for agitation. Later the crew built a 300-gallon tank for mixing and storing the slurry (fig. 2). Power was applied by a 1-1/2 horsepower electric motor through a reduction gear. The paddles were located so that they barely cleared the bottom of the tank. This is advisable because the dry powder tends to "lump up" and settle to the bottom.

Air Tankers

In the early stages of the air-tanker operation two 300-gallon tanks were installed on timber platforms 10 feet high to allow for gravity loading to the planes. The chemical was mixed in 50-gallon drums on top of the main tank. Power for mixing came from an electric power drill attached to a propeller. The mixture then was drained into the main tank. It usually required about 4 man-hours to fill the 300-gallon tank with chemical mixed at 4 pounds per gallon of water.

As the air tanker operation expanded it was obvious that this crude method of mixing could not meet the demands, so other methods were explored. Transit-mix-concrete trucks were used on the first two

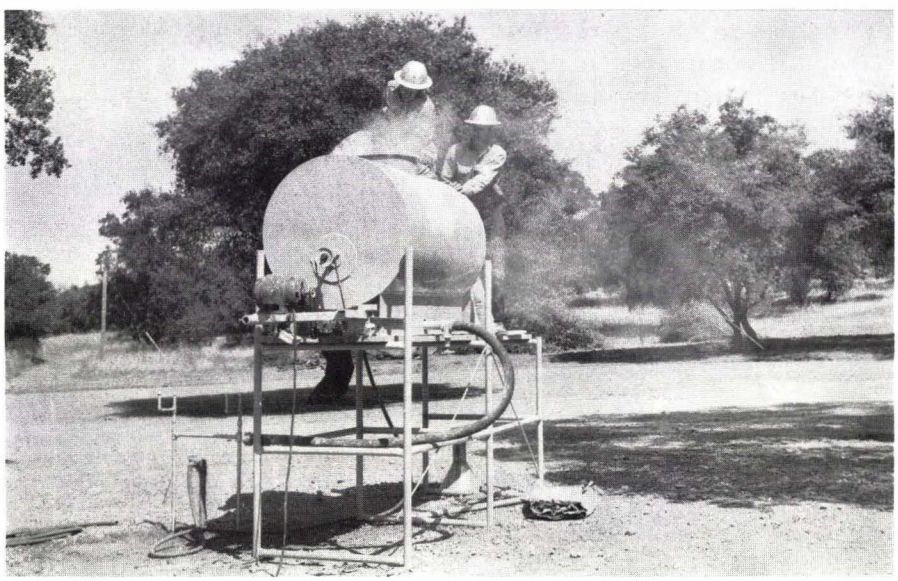


Figure 2.--Mixing sodium calcium borate in 300-gallon electrically agitated tank.

large-scale air operations. One 6-yard mixer and two 3-yard mixers supplied 7 air tankers making 10-minute round-trip circuits to the Cornwell Fire, Cleveland National Forest. These three mixers produced 2,200 gallons per batch. The slurry was pumped by a small centrifugal pump directly from the mixer to the plane. Two minutes were usually required to load a plane with 100 gallons. This method of mixing and loading was extremely messy and expensive.

To speed up loading and eliminate the pump, a 1,600-gallon vacuum tank commonly used in oil-field work was tried on the next large fire. By reversing air flow, this unit was able to receive the slurry from mixers, store it, and supply the planes without using an auxiliary pump.

The next improvement was a jet mixer to replace the concrete mixers. It introduced water at 400 P.S.I. (pounds per square inch) through an orifice at the bottom of a steel hopper; dry chemical was fed into the hopper at regular intervals, and the resultant mix was delivered into a small tank (fig. 3). Then a large vacuum tank (fig. 4) sucked up the retardant. A piece of hard hose was needed on the end of the vacuum-tank delivery line to prevent crimping where the hose bends over the plane's cowling. This 400-P.S.I. mixer was capable of producing 3,600 gallons of slurry per hour.

Because few fire crews have pumps of 400 P.S.I. capacity, the Western Fire Equipment Company conducted tests to determine if the ejection principle (fig. 5) could be used to mix the sodium calcium borate slurry at lower operating pressures and discharge rates. The most recent mixer tested is designed to mix the slurry at 100-150 P.S.I. with a discharge of about 20 gallons per minute (fig. 6). This piece of equipment does a good job of mixing. It is simple and inexpensive to operate, and the ready mixed borate can be transferred to air tankers, ground tankers, or storage tanks.

STORING THE MIXTURE

Dry, unmixed powder can be stored in sacks indefinitely without caking or deterioration if it is kept dry.

Field experiences show that the following precautions should be observed when storing sodium calcium borate slurry:

1. An access hatch is needed at the top of the tank.

2. All baffles and outlet screens should be removed from the tank.

3. Control valves at the tank should be of the open-bore type.

4. Tank should be raised high enough to permit gravity flow to ground or air tanker (at least 10 feet above ground).

Figure 3. --Jet mixer first used on McKinley Fire, San Bernardino National Forest.

Figure 4. --Oil field vacuum truck used to transfer borate from jet mixer to air tanker.

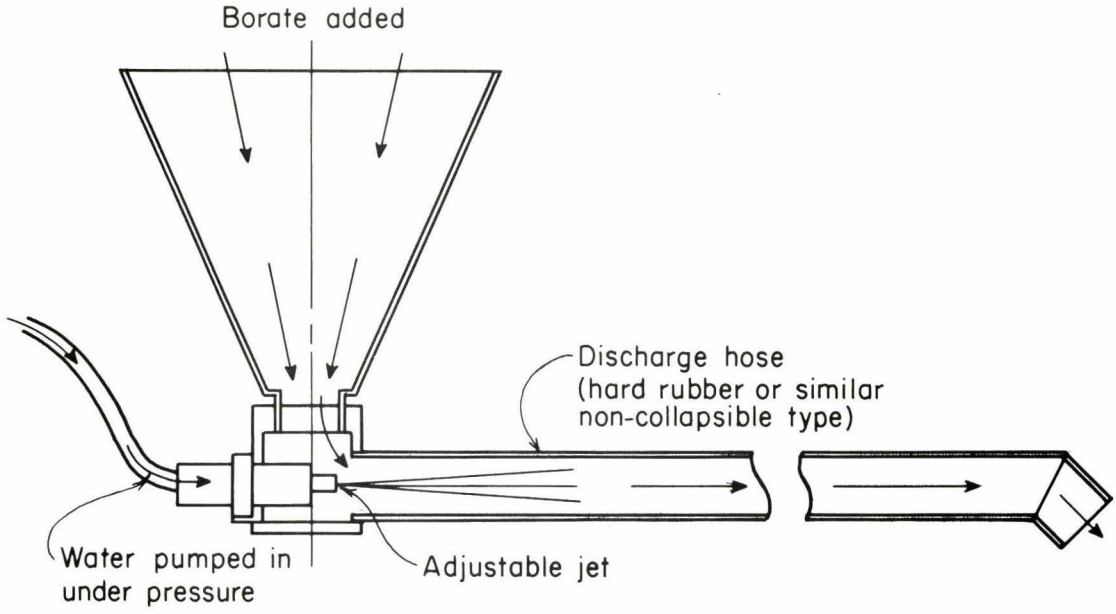


Figure 5. --Diagram of ejector mixer.

Figure 6. --Dry chemical mixing device designed by Western Fire Equipment Company.

5. A stiff plastic or hard rubber hose at least 2 inches in diameter should be provided for delivery from tank to plane.

CHEMICAL RETARDANT COSTS

The cost of retardant is a factor that must be considered. The present cost of sodium calcium borate is $101.50 per ton F.O.B. Wilmington, California. Shipping costs for 5- to 10-ton lots would add 1 cent per pound from Wilmington to Sacramento, 1-1/2 cents to Redding.

If borate is mixed at the rate of 4 pounds per gallon, the retardant alone will average about $0.18 per gallon. When you consider that the cost of getting plain water on a fire in California ranges from $0.50 to $6.00 per gallon, the additional few cents is insignificant.

RESULTS OF FIELD TRIALS

Our evaluations of borate use are based on written reports by the men who used it in the field, our own observations on the fireline, and interviews with fire fighters.

Use by Ground Tankers

Ground tankers applied 6,900 gallons of borate to about 22,000 feet of fire edge on 26 fires during the 1956 season (table 1). They were able to test the retardant for several different uses, and on several occasions could compare it directly with plain water pumped from similar equipment in the same situation.

Direct attack in heavy fuels. --Sodium calcium borate is much more effective than water for putting out fire in heavy fuels. Fire fighters used the retardant on down logs and stumps on the Keno Camp Fire, Shasta-Trinity National Forest, August 1956. They said that it took about one-third as much borate slurry as water to hold down and extinguish the fire. Examination of some of the heavy fuels that had been extinguished by borate revealed a crusty surface layer of dry powder which kept the fire from rekindling after the first spray had knocked down the flame.

Direct attack in light fuels. --Borate appears to knock down fire in grass and brush as quickly as water. An advantage over water is that it eliminates most rekindles because a residual coat of dry chemical is left on the fuel. In effect, fire in grass and light brush can be knocked down faster with this chemical attack.

Pretreatment. --The chemical can be used successfully in rocky areas, such as cliffs or lava beds, where it is impossible to build fireline with a bulldozer and impractical to construct hand lines.

Table 1.--Borate use by ground tankers, 1956

Date	Place of use[1]	Name of fire	Acres	Gallons used	Type of use[2]	Fuel[3]
6/9	San Diego Co.	Fink	45	500	DA	G & B
6/13	Amador Co.	McQuan Ranch	1	50	PRE	G
6/18	San Diego Co.	Barona	3	500	DA	B
6/26	Amador Co	Southern Pacific	75	160	DA	G
6/28	Calaveras Co.	Parriots Ferry Expt.	1.3 m. roadside	500	PRE	G
7/1	Calaveras Co.	Bruner Mine	.2	50	DA	G
7/3	Amador Co.	City Fire #1	1.5	50	DA & PRE	G & B
7/11	San Diego Co.	Julian	20	160	DA	B
7/13	Calaveras Co.	Etna King Mine	3	250	DA	G
7/13	Calaveras Co.	Hwys. #4, #2	.5	100	DA	G
7/20	Shasta-Trinity NF	Big Lake	.5	200	DA & PRE	L
7/21	Calaveras Co.	Utica Mine	Spot	200	DA	G
7/30	Shasta-Trinity NF	Raccoon	140	200	PRE	S
8/5	Amador Co.	City Fire #2	.75	100	PRE	G
8/10	Shasta-Trinity NF	Mile Post 315.90	.3	75	DA	L
8/14	L. A. Co. Fire Dept.	Park	1,200	250	PRE	B
8/14	San Diego Co.	Sutherland #170	2,400	150	DA	B
8/17	Shasta-Trinity NF	Keno	9.6	2,000	DA	T
8/21	Amador Co.	Ballard Mine	60	180	DA & PRE	G & B
8/26	Shasta-Trinity NF	Mile Post 321.00	.07	75	DA	G
9/4	Shasta-Trinity NF	Berry Picker	.03	30	DA	L
9/8	L. A. Co. Fire Dept.	Dunsmore	778	600	PRE	B
9/24	Amador Co.	Riella	1.5	180	DA & PRE	B
9/25	Shasta-Trinity NF	Mile Post 314.90	.04	110	DA	G & B
9/25	Amador Co.	Masson	40	150	DA & PRE	G
9/30	Amador Co.	Orr	3	80	DA & PRE	G

1/ Name of county for California Division of Forestry fires, name of national forest for U. S. Forest Service fires.

2/ DA: Direct Attack--sodium calcium borate was applied directly to fire;
PRE: Pretreatment--borate was applied ahead of fire edge, and fire allowed to burn up to chemical fireline.

3/ G - grass, T - timber, B - brush, L - litter, S - slash.

Also, natural or existing firebreaks can be widened or strengthened at weak points by pretreating fuels with retardant.

Controlled burning. --One field unit sprayed 7,064 feet of line 3 to 5 feet wide in grass along a state road right-of-way. Seventeen days later, the crew started the hazard-reduction fire. They reported that fire crept through the sprayed line only at the few places where fuel was not covered sufficiently. For maximum protection, they said, it is not necessary to saturate the fuels, but rather to cover all fuel surfaces. (In this case about 1.8 gallons per 100 square foot gave adequate coverage.)

Spot fires. --The risk of spot fires can be reduced by spraying hazardous fuels inside the fireline. Both low-hanging branches and dry fuels under them should be treated (fig. 7).

Backfire lines. --On the 800-acre Dunsmore fire on the Angeles National Forest, 3,000 feet of line 8 feet wide was treated through medium brush. Backfiring was done successfully from this line even though adverse wind conditions caused many sparks to be blown into the treated area. No spot fires occurred in the sprayed area, but spots were ignited in the unsprayed brush.

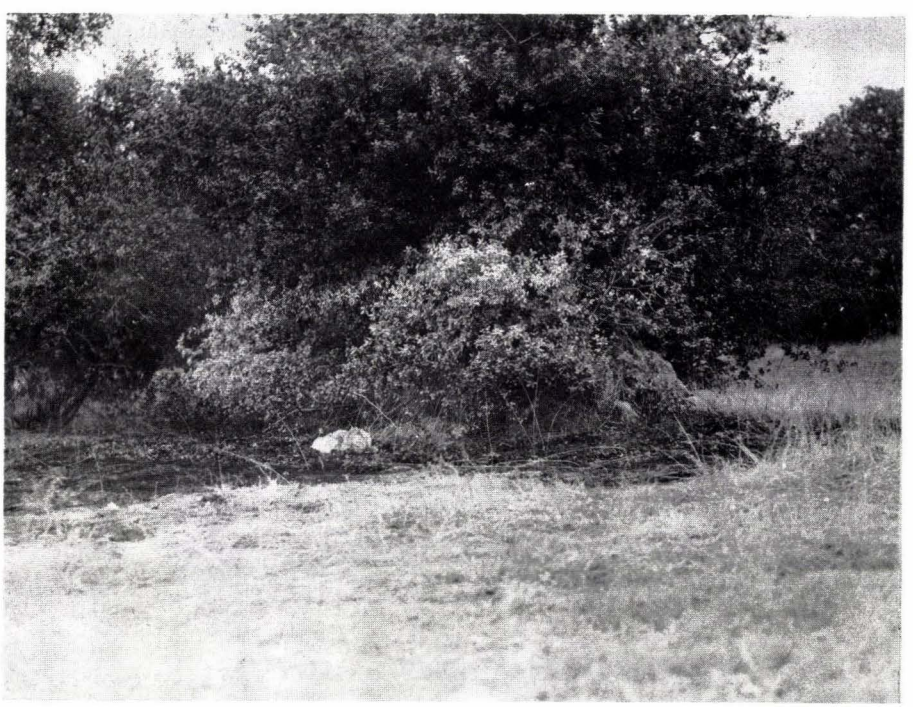


Figure 7. --Spot fires can be reduced by pretreating low-hanging branches of oak trees and other hazardous fuels inside the fireline.

Mopup. --The density of the borate mixture makes penetration through duff and other finely compacted fuels difficult. Fire burning up to a pretreated line in deep duff fuels will drop down and smolder underneath the treated line and then rekindle. The chemical does appear to decrease heat and rate of spread, however, and it remains effective longer than water. To give best results, hand tools should be used in close conjunction with wet mopup in duff. On one sawdust fire, borate was stirred into the entire depth of the pile--2 to 3 feet. No reignitions occurred after the first pass through the pile. This is seldom possible in mopping up sawdust fires with plain water.

Use by Air Tankers

The air-tanker operation was originally supposed to be a small-scale project. It turned out to be a full-scale fire-fighting operation. In fact, almost 10 times as much retardant was dropped by planes on 14 fires as was applied by ground tankers on 23 fires. The borate drops--of 100-gallon loads--assured control on 11 of the 14 fires, were of no help on 2, and had an adverse effect on 1 because the drop knocked down a backfire and resulted in lost fireline (table 2). It was on the air-tanker operation that the prolonged effects of chemical retardants really demonstrated their value.

Pretreatment. --Air tankers can build a chemical firebreak in advance of the fire where it is impossible or unsafe for men to work, as in deep saddles and other critical locations. On the Inaja Fire, Cleveland National Forest, chemical retardant was dropped at several locations on saddles. The drops were not only effective in delaying the fire, but once 6 drops in a saddle resulted in a white island of borate when the chemical line was flanked by the fire (fig. 8). The drops left a crusty layer of chemical on fuels and on the ground surface (fig. 9).

Chemical attack from the air can strengthen roads or natural barriers and other firebreaks. Borate drops were used to reinforce a rocky ridge on the west side of the San Diego River Canyon on the Inaja fire and held the fire in light brush.

Retardants can fireproof local areas where spot fires are likely, such as exposed slopes next to the main fire. This method was used effectively on the McKinley Fire on the San Bernardino Forest on the east side of Deep Creek.

Direct attack. --Air tankers can knock down and hold small fires and spot fires. Two hundred gallons of chemical were dropped on the 0.3-acre Bohemotash Fire (Shasta-Trinity National Forest). Pine needles and duff coated with chemical did not produce spot fires although a 40 mile-per-hour wind caused considerable spotting in the untreated area within the control line. Part of the borate landed in a

Table 2.--Summary of borate use by air tankers, 1956[1/]

Date	Place of use[2/]	Name of fire	Size of fire	Gallons used	Effect on fire[3/]		
					Help	No help	Adverse
			Acres				
8/12	Shasta Co.	Beegum #1	500	200	x		
8/20	Shasta-Trinity NF	Cinder Cone	Spot	200	x		
8/22	Shasta-Trinity NF	Lava Cave	1	200	x		
8/25	Shasta-Trinity NF	Bohemotash	1	200	x		
8/26	Shasta Co.	Beegum #2	150	400			x
9/9	Angeles NF	Dunsmore	850	80	x		
9/10	Cleveland NF	Pine Mt.	6,850	6,200	x		
9/11	Cleveland NF	Cornwell	2,500	6,100	x		
9/12	Riverside Co.	DeLuz	1,100	200		x	
9/22	San Bernardino NF	McKinley	10,250	25,400	x		
9/25	Riverside Co.	Portrero	520	700		x	
9/30	Shasta-Trinity NF	Steep Hollow	2	700	x		
11/23	San Bernardino NF	E. Highland	15,296	2,410	x		
11/24	Cleveland NF	Inaja	45,000	23,000	x		

1/ Tabulation of reports from field officers of U.S.F.S. and C.D.F. Prepared by California Forest and Range Experiment Station and California Region, U.S.F.S.

2/ Name of county for California Division of Forestry fires, name of national forest for U. S. Forest Service fires.

3/ Definitions:
"Help" - a deciding factor in assuring control or a definite help to ground forces.
"No help" - fire would have been controlled at same size without air drop.
"Adverse" - put out backfire and made control more difficult.

Figure 8.--"Borate Saddle" near Sawday Fire Camp--Inaja Fire, Cleveland National Forest. Fire was slowed up by sodium calcium borate drops in this chamise and sage.

Figure 9.--Crusty layer of sodium calcium borate on fuels and soil after drops on Inaja fire.

patch of white fir reproduction. The fire crowned in the thicket but only went up as far as the chemically covered foliage and then dropped back to the ground.

For direct attack drops with retardant, it is desirable that about one-half of the load fall on the fire and the other half on the unburned fuels just outside the fire.

Air tankers dropping retardants can knock down and hold slopovers and other critical points on large fires. Chemical drops on the Cornwell Fire (Cleveland National Forest) held several slopovers until hand crews could cut lines around them. Experienced firemen at the scene said that these slopovers could not have been picked up without the aid of the borate drops. Control of the fire could easily have required another day's shift.

Limitation of air drops.--Air tankers dropping chemical retardants cannot knock down hot, rolling fires in brush or timber. This was attempted on the Pine Mountain Fire (Cleveland National Forest) and had no effect on the fire. The fire was rolling over tractor firebreaks at the same time. Similar attempts were made on two other large fires in southern California. The drops were wasted on fast moving fronts.

PROBLEMS YET TO BE SOLVED

Equipment is needed to simplify and speed up the mixing of chemicals for ground and air tankers. The most promising solution seems to be the injector type of mixer now being tested.

Since conventional pumps and nozzles were not made to pump and apply a slurry-type mixture, suitable equipment must be developed to do the job. It is possible that the chemical can be expelled by gas or rocket power.

We still need to know just how much sodium calcium borate is required to exert significant retarding effects on fires in different fuel types and densities. Fire fighters need more guidelines than the limited field experience and judgment now available.

CONCLUSIONS

Ground attack by tankers can be strengthened by using sodium calcium borate. Here are some of the ways this chemical fire retardant can pay dividends:

1. The edge of a fire can be knocked down faster and with greater confidence because there will be fewer reignitions if the chemicals are used instead of plain water.

2. Pretreated lines can be used successfully on the flanks, rear, and cooler parts of the head of fire.

3. The danger of spot fires can be reduced by fireproofing hazardous fuels inside the fireline.

4. Roads, ridgetop clearings, and other firebreaks can be widened quickly and safely.

5. Pretreated backfire lines can be prepared rapidly on controlled burns and wildfires.

Tactical air support on going fires is a reality principally because of the effectiveness of sodium calcium borate dropped by the 1956 air tanker squad. Borate proved that it can do these jobs:

1. Lightning fires, spot fires, and slopovers on large fires can be knocked down and held by air attack.

2. Chemical-retardant lines can be built ahead of fires in areas inaccessible to men or where it is unsafe for them to work.

3. Firebreaks can be strengthened from the air safely.

4. Safety islands can be built around isolated equipment and buildings.

5. Areas susceptible to spot fires can be fireproofed.

The 1955 and 1956 shakedown tests have proved that a good chemical fire retardant can be an effective fire tool. Since existing conventional fire-fighting equipment was used to mix and apply sodium calcium borate, mechanical problems often obscured the favorable results. The development of proper equipment will help reveal the true potential of chemical fire retardants for wild land fire control.

APPENDIX--LABORATORY TESTS

Pressure Losses due to Friction

The Arcadia Equipment Development Center of the Forest Service found that at low rates of flow the pressure loss for sodium calcium borate mixtures was much higher than that for clear water. (The effect of this loss was illustrated on a San Diego fire when the tank-truck operator was unable to pump borate 300 feet up a steep slope without bursting the hose.) However, for flows of 50 to 60 gallons per minute, the friction loss was about the same as for water (fig. 10).

The Western Fire Equipment Company found that when the borate is first mixed by injection at 100 P.S.I. the solution is discharged in a liquid form during the first 3 minutes. Thereafter, the solid particles seem to swell, apparently because of the absorption of moisture, and the liquid turns into a slurry. If the borate mixture could be moved during those first 3 minutes, some of the loss due to friction can be overcome.

Abrasiveness

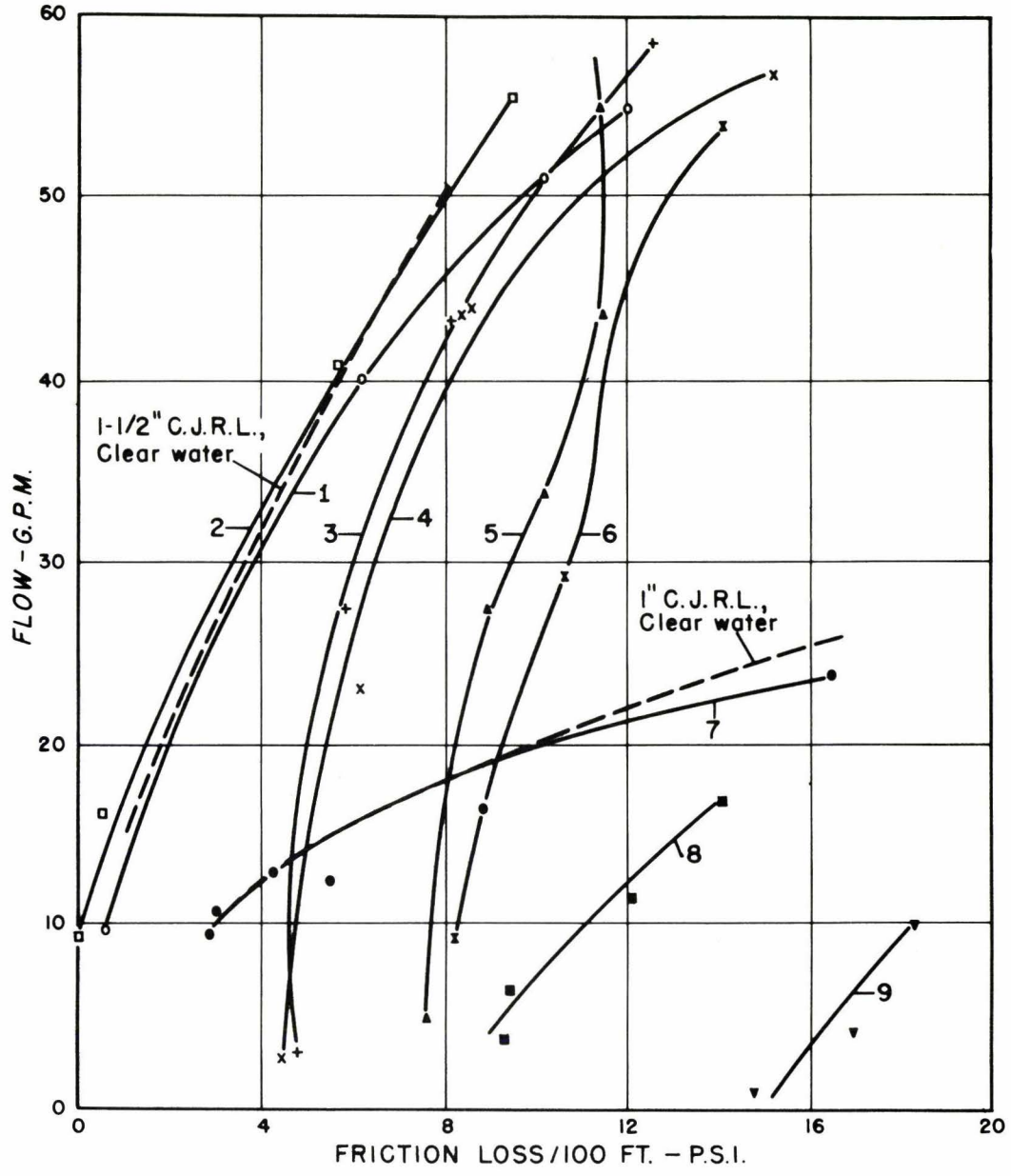
Measurements of the Berkeley 4-stage pump on the tanker stationed at Dunsmuir showed wear of 0.063 to 0.10 inch between the suction eye and wear ring of each stage, and of 0.085 inch in the tail-shaft bearing at the discharge end of the pump. The impeller shaft was badly worn by packing rings where it is supported by the tail-shaft bearing. The unit operated a little over 200 hours and pumped about 2,700 gallons of chemical on 7 fires. More than 50 percent of the equipment-hours were consumed during the mixing process since it was necessary to run the pump during this entire operation. The abrasion is high compared to that experienced with clear water, and is more than normally occurs with dirty irrigation water.

The California Division of Forestry made an endurance test on a Berkeley 2-stage pump commonly used on State fire trucks. Borate mixed by the injector process was pumped through the unit at 8 gallons per minute at 100 P.S.I. The mechanical seal around the pump shaft failed after 7 hours and 20 minutes of operation.

Following are wear factors measured after the pump was dismantled:

Carbon side of mechanical seal worn out

Rubber seat on discharge valve worn out



1 - Goodall nylon 1-1/2" hose 2 lb/gal. — o
2 - Cotton jacket rubber lined 1-1/2" hose 2 lb/gal. — □
3 - Cotton jacket rubber lined 1-1/2" hose 4 lb/gal. — +
4 - Goodall nylon 1-1/2" hose 4 lb/gal. — x
5 - Cotton jacket rubber lined 1-1/2" hose 5 lb/gal. — ▲
6 - Goodall nylon 1-1/2" hose 5 lb/gal. — ⧗
7 - Goodall nylon 1" hose 2 lb/gal. — ●
8 - Goodall nylon 1" hose 4 lb/gal. — ■
9 - Goodall nylon 1" hose 5 lb/gal. — ▲

Figure 10. --Friction loss and flow rate of borate slurry, by size and type of hose. (Arcadia Equipment Development Center.)

Suction side of first stage impeller--. 007 inch wear

Pressure side of first stage impeller--. 008 inch wear

Suction side of second stage impeller--. 015 inch wear

Pressure side of second stage impeller--. 007 inch wear

Wear ring first stage--. 004 inch wear

Wear ring second stage--. 005 inch wear

Case bushing--. 005 inch wear

Tail bushing--. 011 inch wear

Tail end of pump shaft--. 003 inch wear

Pumps from Amador, Calaveras, and Orange Counties were also examined carefully after being used during the 1956 field season. There was no record of total hours of operation, but each part listed above was worn at least as much as those involved in the endurance test and some parts were worn twice as much.

As a result of the pump damage experienced in 1956 and observations made during the test, the Division of Forestry plans to discontinue pumping sodium calcium borate through their conventional fire pumps except during emergency situations. They are, however, planning to work on the development of pumps which can handle borate.

Because of its abrasiveness, sodium calcium borate suspension should not be pumped through positive displacement pumps. In an endurance test at the Arcadia Equipment Development Center, a small positive displacement pump pumping sodium calcium borate failed after 10 minutes. These pumps have close tolerances and are designed to pump clear water only.

An open vane centrifugal pump, made for handling irrigation water, however, pumped 17,000 gallons of chemical in 3 air-tanker operations without any damage. This pump was subjected to a 100-hour recirculation pumping test by Arcadia Equipment Development Center. Critical examination of internal parts following the test indicated that the pump could have been operated another 100 hours before repair would be necessary.

Many pump failures in the field tests occurred because the borate was not well mixed when it was pumped on fires. Since an injector mixer can mix the material thoroughly and produce a very stable suspension, it may solve some of the equipment problems.

Corrosive Effects

The United States Borax & Chemical Corporation conducted tests on the corrosive effect of sodium calcium borate, both while wet and after drying on aluminum alloys, mild steel, and brass (table 3). On two aluminum alloys and brass the wet chemical was slightly more corrosive than tap water. On mild steel its corrosive effect was equal to or less than that of tap water. After the wet material dried on these metals very little corrosion occurred.

Wetting Agents

Laboratory tests were made to determine the effect of certain wetting agents on the sodium calcium borate slurry. The results showed that certain agents promote more uniform spreading of the chemical and increase the rate of wetting of the powder. However, while one agent assisted in holding the chemical in suspension, another caused settling out. Also, some of the agents alone tend to induce corrosion or rusting of mild steel and iron. This means that the tanker would have to be rinsed thoroughly after each use if these wetting agents were used.

Table 3.--Corrosion tests in sodium calcium borate slurries[1/]

Item	Time of test 10-12 days		Time of test 25 days		Time of test 40 days	
	mg loss	inches/yr	mg loss	inches/yr	mg loss	inches/yr
Aluminum Alloy 2024-0, density 2.88 g/cc (strong but not corrosion-resistant; similar to the alloy used for airplane surfaces, according to Alcoa):						
Tap water	0.4	.00006	-	-	0.5	.000024
Wet slurry	1.5	.00030	2.7	.00024	4.9	.00027
Dried slurry	-	-	0.1	.000009	0.1	.000006
Aluminum Alloy 6061-T4, density 2.70 g/cc (corrosion-resistant but not strong, according to Alcoa):						
Tap water	2.5	.00041	-	-	4.6	.00023
Wet slurry	3.0	.00069	3.9	.00036	4.8	.00028
Dried slurry	0.3	.00006	0.4	.00004	0.5	.00003
Mild Steel (density 7.83):						
Tap water	20.0	.00113	-	-	178.3	.0030
Wet slurry	17.7	.00127	22.5	.00071	62.6	0.00123
Dried slurry	-	-	-	-	0.1	0.00006
Brass (density 8.4):						
Tap water	0.4	.000021	-	-	0.2	0.000003
Wet slurry	1.9	.000127	2.5	.000074	3.0	0.000055
Dried slurry	1.3	.000096	1.4	.000043	1.4	0.000027

DISCUSSION:

The rate of corrosion (inches per year) of the aluminum alloys and the brass was higher for the first 10 days than for 25 and 40-day periods. The wet slurry was somewhat more corrosive to the aluminum alloys than tap water. It was about the same as tap water for 10 days on mild steel, but not quite as corrosive as tap water for a period of 40 days. Although the wet slurry was considerably more corrosive to brass than tap water, the corrosion rate was low.

The aluminum alloy similar to that used on airplane surfaces (2024-0) resisted sodium calcium borate slurry somewhat better for short periods than alloy 6061-T4 which was stated by Alcoa to be more corrosion-resistant. Corrosion rates on both types were low.

The corrosion caused by the drying of sodium calcium borate slurry on all these metals is very small. It was less than tap water except in the case of brass.

1/ From: United States Borax & Chemical Corporation, Research Division Report 2R-136-10. Corrosive effect of FIREBRAKE. 3pp., December 17, 1956.

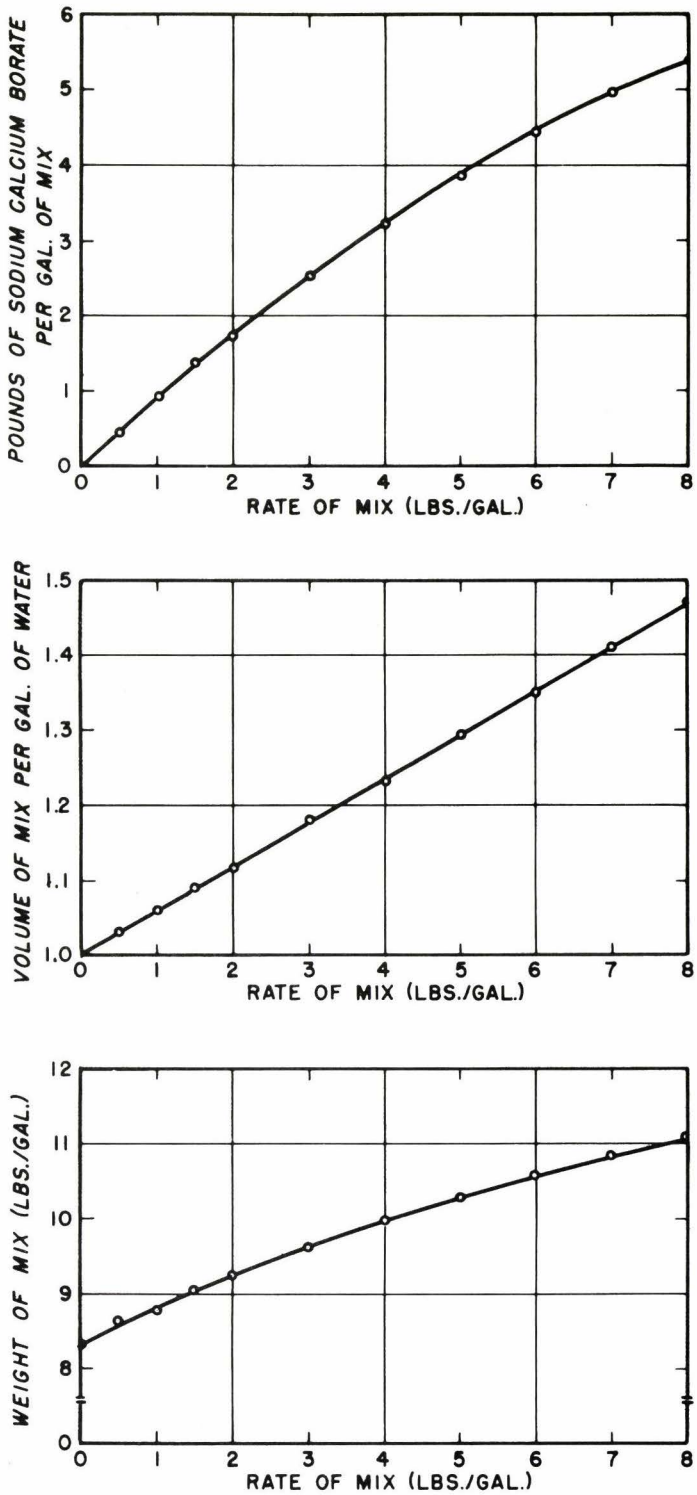

POUNDS OF SODIUM CALCIUM BORATE PER GAL. OF MIX
RATE OF MIX (LBS./GAL.)
VOLUME OF MIX PER GAL. OF WATER
RATE OF MIX (LBS./GAL.)
WEIGHT OF MIX (LBS./GAL.)
RATE OF MIX (LBS./GAL.)

Figure 11. --Volume and weight of sodium calcium borate slurry at specified concentrations in water.